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Implementation of Lean Manufacturing Tools in Garment Manufacturing Process Focusing Sewing Section of Men's Shirt

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ABSTRACT

Traditionally operated garment industries are facing problems like low productivity, longer production lead time, high rework and rejection, poor line balancing, low flexibility of style changeover etc. These problems were addressed in this study by the implementation of lean tools like cellular manufacturing, single piece flow, work standardization, just in time production etc.

After implementation of lean tools, results observed were highly encouraging. Some of the key benefits entail production cycle time decreased by 8%, number of operators required to produce equal amount of garment is decreased by 14%, rework level reduced by 80%, production lead time comes down to one hour from two days, work in progress inventory stays at a maximum of 100 pieces from around 500 to 1500 pieces. Apart from these tangible benefits operator multi-skilling as well as the flexibility of style changeover has been improved.

This study is conducted in the stitching section of a shirt manufacturing company. Study includes time studies, the conversion of traditional batch production into single piece flow and long assembly line into small work cells.

Key Words: Lean manufacturing, Just In Time, Cellular manufacturing, Time study, Single Piece Flow

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ABBREVIATIONS

CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CI	Continuous Improvement
FSVSM	Future State Value Stream Mapping
ISVSM	Ideal State Value Stream Mapping
JIT	Just in Time
MTM	Methods Time Measurement
PDCA	Plan Do Check Act
PFD	Personal Fatigue and Delay
PMTS	Predetermined Motion Time Systems
PSVSM	Present State Value Stream Mapping
SAM	Standard Allowed Minutes
SMED	Single Minute Exchange of Dies
TMU	Time Measurement Unit
TPM	Total Productive Maintenance
TPS	Toyota Production System
VSM	Value Stream Mapping
WIP	Work in Progress

1 INTRODUCTION

1.1 Background

Due to the increasing labor wage in developed countries, the apparel manufacturing has been migrating from the high wage developed world to low wage developing countries (Bheda, Narag and Singla, 2003). Even though the labor cost is cheaper than in developed countries; due to the specific market nature of the garment industries for example: the short production life cycle, high volatility, low predictability, high level of impulse purchase, the quick market response; garment industries are facing the greatest challenges these days (Lucy Daly and Towers, 2004).

Garment industries in developing countries are more focused on sourcing of raw material and minimizing delivery cost than labor productivity because of the availability of cheap labor. Due to this, labor productivity is lower in developing countries than in the developed ones. For example, labour is very cheap in Bangladesh but the productivity is poor among other developing countries (Shahidul and Syed Shazali, 2011). Similarly, the cost of fabric is a major part of the garment so there seems to be great need for improvement in this sector. Even in developing countries the CAD and CAM system for fabric cutting has been implemented to save fabric. Now the worry is about labor productivity and making production flexible; because the fashion industry is highly volatile and if the orders are not fulfilled on time, the fear for losing business is real.

Even today, industries are getting the same or more volumes (orders), but the number of styles they have to handle has increased drastically. Earlier industries were getting bulk order so there is no need to worry; if the production line was set for the first time it would run for a month or at least a week or two. But nowadays due to small order quantities and complex designs, the garment industry has to produce multiple styles even within a day; this needs higher flexibility in volume and style change over (Shahram and Cristian, 2011).

In some cases it has been observed that, in developing countries the garment industries are run as family business lacking skilled personnel as well as capital to implement new technologies for improving productivity and flexibility. Because of this, industries have been running in a traditional way for years and are rigid to change. They are happy as long as they are sustaining their business. They don't have much confidence and will towards innovation over old processes. Now the time has come to struggle with global market demand and niche market in garment industries if they want to run it further (Gao, Norton, Zhang and Kin-man To, 2009).

This volatility of styles can be addressed only by flexibility in manufacturing. The best way to cope with all these challenges is the implementation of lean manufacturing. This will serve our purpose of flexibility and save a lot of money by reducing production lead time, reducing the inventory, increasing productivity, training operators for multiple works, and by reducing rework.

1.2 Research Problems

The major problem people faced in garment industry is stitching; most of time failure to meet delivery time is because of stitching. Stitching operations (with respect to cutting and finishing) needs high skill as well as quality work, because of difficulty associated with repairing of products sewed with wrong specifications. Thus we have to give more attention to stitching than to cutting and finishing of garments.

Firstly, High WIP in traditional type of batch production is the major problem faced by industries. Due to high WIP the throughput time as well as rework is very high. In some cases, even though the operator has completed the stitching operations the garment cannot be packed because of high WIP. Due to huge WIP, the defective parts are hidden inside the batches and it is very difficult to clear them while completing the final order quantity. This is the reason why garment professionals seem to work like fire fighters;

because they are always in a hurry for searching the missing garment pieces all over the shop floor.

Secondly, in batch processing flexibility cannot be achieved easily; which is the current demand of garment industry. This is obstructed by the decreasing order size and increasing number of styles. So to meet this requirement production layout should be designed such that it should hold minimum WIP and should be flexible enough to the changing of order.

Thirdly, in batch process operators are given specific jobs, so the operator knows one or a few more operations only. Though he (she) may have good skill and can work more efficiently on one (allocated job only) operation; he (she) cannot work immediately on some other operation. This is another need of today's world, because the fashion is changing frequently and the work force should be capable enough to cope with this change. To achieve this operator should be multi-skilled; which can be served by regular training and converting long assembly lines into small manufacturing cells.

Workload fluctuation among operators is another problem in batch processing, because one operator is given one operation at a time. So the operator who is performing easier and low time consuming jobs can pile up a huge amount of WIP whereas in the critical operations (operations which need more time and skill) there is lagging causing unbalanced WIP in-between machines and the work load is not proper among operators. This research tries to address all these problems of garment industry by implementing lean manufacturing in the case company.

1.3 Research Objective

Lean manufacturing is an operational strategy oriented towards achieving the shortest possible cycle time by eliminating wastes. The term lean manufacturing is coined to represent half the human effort in the company, half the manufacturing space, half the investment in tools and half the engineering hours to develop a new product in half the time. These benefits can be achieved only if the concept is religiously followed in the organization. In simple terms lean manufacturing is without waste. Thus the objective of this research is to find out how we can use lean manufacturing to achieve the following:

- To meet customer demand on time by eliminating non value added work from the process
- To minimize the work in process inventory
- To create flexibility of style changeover
- To reduce rework percentage
- To create a pool of multi-skilled operators who can respond quickly for changing style

1.4 Research Approach

The initial step in this research is to systematically study and define the history of the lean manufacturing concept and its different tools and techniques. It will then examine some most used lean manufacturing tools and techniques. This will be followed by the study of the existing production system of the case company for example the existing production layouts, inventory movement systems, work balancing methods and other different variables which needs to be improved for the betterment of the existing system.

To address the current issues of the industry, the researcher tries to find out the standard operation time for each operation by using time study techniques and will try to standardize all the operations. Once the standard operation time is obtained work will be done to find out the best suitable production layout and WIP movement methods, which will help to get flexibility in style changeover, should reduce the production lead time, create operator multi-skilling etc. After doing these entire things as paper work, the researcher will implement the research outcomes in the company and the improvement will be measured against the existing process. Basically, this is quantitative research where the researcher is a part of the organization during the study.

1.5 Report Construction

The whole report consists of seven chapters. The first chapter describes the need of the research, research objectives and research approach. Literature review about lean manufacturing, layout designs, time study and assembly line balancing is described in chapter two. Industry background and garment manufacturing processes are described in the third chapter followed by the research methodology, data collection methods etc. in chapter four.

The fifth chapter includes the analysis part of the research; in this chapter different parameters are compared between existing production systems and the new recommended system. Chapter six is about the research summary, conclusion of research, its limitations and recommendation for further study, followed by the list of reference in the seventh chapter.

2 LITERATURE REVIEW

2.1 History of Lean

During II world war, the economic condition of Japan was heavily destroyed. Due to this there was scarcity of fund resulting in limiting access to corporate finance. In this situation, neither Toyota was able to set up a mass production system like their American counterparts, nor it was possible to layoff the employees to reduce their cost due to legislation. Anyhow Toyota had to devise a new system for reducing costs to sustain in the market. So they decided to produce a small batch of products which would reduce inventories; it means they would need less capital to produce the same product. But this is obstructed by the practical difficulty of changing tools and production lines frequently. To cope with this problem they started making multipurpose tooling systems in their machines and trained their employees in changeover time reduction methods. At the same time, Toyota realized that investing in people is more important than investing in bigger size machinery and continues employee training throughout the organization. This motivates all employees and they are more open to the improvement process and everyone started giving their input to the company.

In this way, short production runs started by Toyota became a benefit rather than a burden, as it was able to respond much more rapidly to changes in demand by quickly switching production from one model to another (Drew, Blair and Stefan, 2004, p. 5-6). Toyota didn’t depend on the economies of scale production like American companies. It rather developed a culture, organization and operating system that relentlessly pursued the elimination of waste, variability and inflexibility. To achieve this, it focused its operating system on responding to demand and nothing else. This in turn means it has to be flexible; when there are changes in demand, the operating system is a stable workforce that is required to be much more skilled and much more flexible than those in most mass production systems. Over time, all these elements were consolidated into a new approach to operations that formed the basis of lean or Toyota Production System.

2.2 Definition of Lean

The popular definition of Lean Manufacturing and the Toyota Production System usually consists of the following (Wilson, 2009, p. 29-30).

1. It is a comprehensive set of techniques which when combined allows you to reduce and eliminate the wastes. This will make the company leaner, more flexible and more responsive by reducing waste.
2. Lean is the systematic approach to identifying and eliminating waste through continuous improvement by flowing the product or service at the pull of your customer in pursuit of perfection (Nash, Poling and Ward, 2006, p. 17).

According to (Drew et al., 2004, p 25) the lean operating system consists of the following:

- A lean operating system follows certain principles to deliver value to the customer while minimizing all forms of loss.
- Each value stream within the operating system must be optimized individually from end to end.
- Lean tools and techniques are applied selectively to eliminate the three sources of loss: waste, variability and inflexibility.

Thus the organization who wants to implement lean should have strong customer focus, should be willing to remove wastes from the processes they operate on daily basis and should have the motivation of growth and survival.

2.3 Lean Principles

The major five principles of Lean are as follows (Burton T. and Boeder, 2003, p. 122):

Principle 1: Accurately specify value from customer perspective for both products and services.

Principle 2: Identify the value stream for products and services and remove non-value-adding waste along the value stream.
Principle 3: Make the product and services flow without interruption across the value stream.
Principle 4: Authorize production of products and services based on the pull by the customer.
Principle 5: Strive for perfection by constantly removing layers of waste.

2.4 Toyota Production System

It is a manufacturing system developed by Toyota in Japan after World War II, which aims to increase production efficiency by the elimination of waste. The Toyota production system was invented and made to work, by Taiichi Ohno. While analyzing the problems inside the manufacturing environment; Ohno came to conclude that different kinds of wastes (non value added works) are the main cause of inefficiency and low productivity. Ohno identified waste in a number of forms, including overproduction, waiting time, transportation problems, inefficient processing, inventory, and defective products.

Figure 1 shows the Toyota Production System in detail. From this figure it can be seen that TPS is not only a set of different tools but it is the philosophy and integration of different tools and systems to achieve a common goal of waste reduction and efficiency improvement. Each element of this house is critical, but more important is the way the elements reinforce each other. Just In Time (JIT) means removing the inventory used to buffer operations against problems that may arise in production. The ideal of one-piece flow is to make one unit at a time at the rate of customer demand or Takt time. Using smaller buffers (removing the “safety net”) means that problems like quality defects become immediately visible. This reinforces Jidoka, which halts the production process. This means workers must resolve the problems immediately and urgently to resume production.

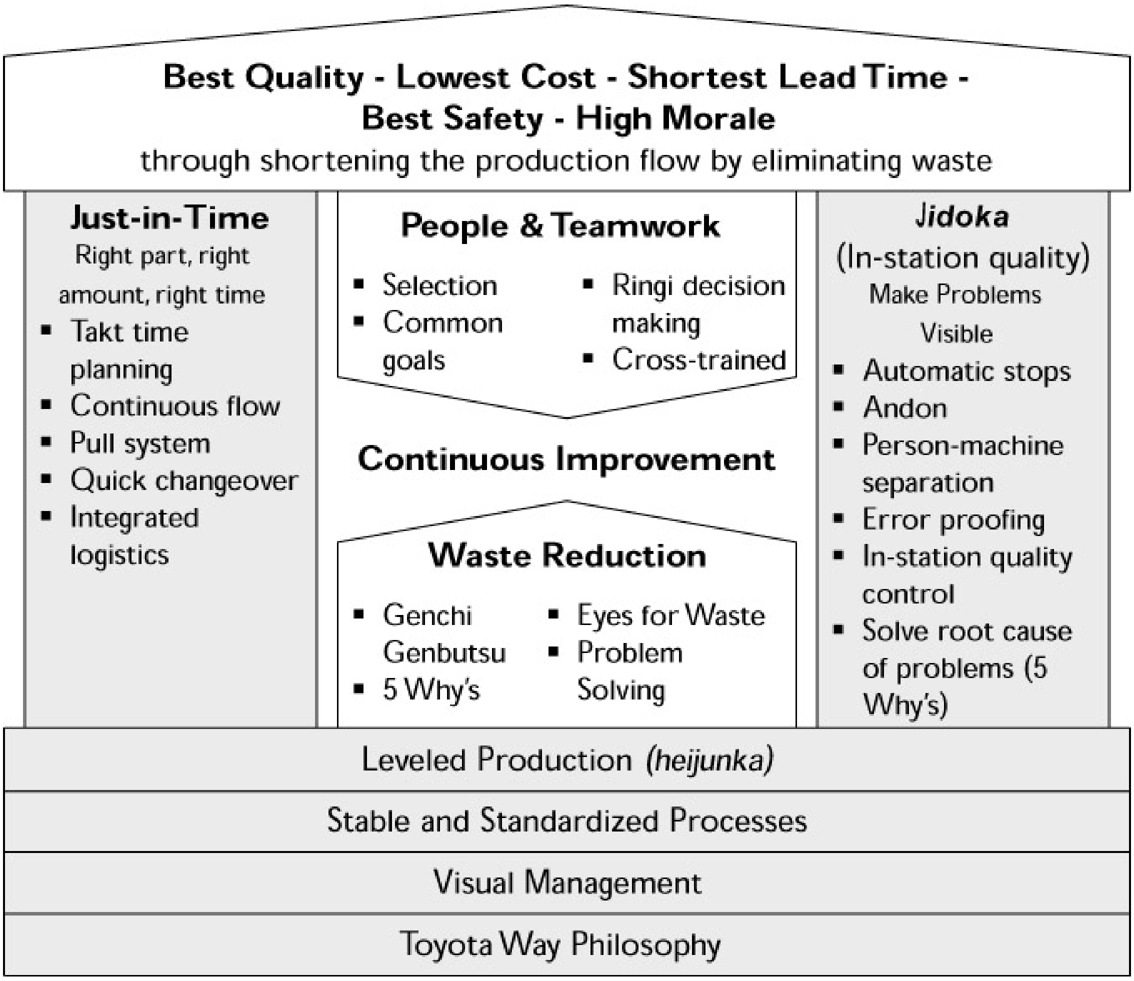

FIGURE 1: Toyota Production System[1]

Stability is at the foundation of the house. While working with little inventory and stopping production when there is a problem causes instability and a sense of urgency among workers. In mass production, when a machine goes down, there is no sense of urgency because the maintenance department is scheduled to fix it while the inventory keeps the operations running. By contrast, in lean production, when an operator shuts down equipment to fix a problem, other operations will also stop immediately due to no inventory creating a crisis. So there is always a sense of urgency for everyone in production to fix problems together to get the machine in working condition and to run the production as soon as possible.

[1] Toyota Way (Liker, 2003, p. 33)

If the same problem occurs repeatedly, management will quickly conclude that this is a critical situation and it should be cracked without any delay. People are at the center of the house, because it is only through continuous improvement that the operation can ever attain this needed stability. People must be trained to see waste and solve problems at the root cause by repeatedly asking why the problem really occurs. Problem solving should be on the actual site of the problem where everything is visible and practical also; this technique of problem solving is called Genchi Genbutsu.

In general TPS is not a toolkit. It is not just a set of lean tools like just-in-time, cells, 5S (sort, stabilize, shine, standardize, sustain), Kanban, etc. It is a sophisticated system of production in which all parts contribute to a whole. On the whole, its focus is on supporting and encouraging people to continually improve the processes they work on.

2.5 Kind of Wastes

According to David Magee, (Magee, 2007, p. 67) different kinds of wastes in a process can be categorized in following categories. These wastes reduce production efficiency, quality of work as well as increase production lead time.

1. **Overproduction –** Producing items more than required at given point of time i.e. producing items without actual orders creating the excess of inventories which needs excess staffs, storage area as well as transportation etc.
2. **Waiting –** Workers waiting for raw material, the machine or information etc. is known as waiting and is the waste of productive time. The waiting can occur in various ways for example; due to unmatched worker/machine performance, machine breakdowns, lack of work knowledge, stock outs etc.
3. **Unnecessary Transport –** Carrying of work in process (WIP) a long distance, insufficient transport, moving material from one place to another place is known as the unnecessary transport.
4. **Over processing –** Working on a product more than the actual requirements is termed as over processing. The over processing may be due to improper tools or

improper procedures etc. The over processing is the waste of time and machines which does not add any value to the final product.

5. **Excess Raw Material -** This includes excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, the extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.
6. **Unnecessary Movement –** Any wasted motion that the workers have to perform during their work is termed as unnecessary movement. For example movement during searching for tools, shifting WIP etc.
7. **Defects –** Defects in the processed parts is termed as waste. Repairing defective parts or producing defective parts or replacing the parts due to poor quality etc. is the waste of time and effort.
8. **Unused Employee Creativity –** Loosing of getting better ideas, improvement, skills and learning opportunities by avoiding the presence of employee is termed as unused employee creativity (Liker, 2003, p. 29).

2.6 Lean Manufacturing Tools and Techniques

There are numbers of lean manufacturing tools which, when used in proper ways will give the best results. Once the source of the waste is identified it is easier to use the suitable lean tool to reduce or eliminate them and try to make waste free systems. Some of these tools are discussed in this chapter.

2.6.1 Cellular Manufacturing

A cell is a combination of people, equipment and workstations organized in the order of process to flow, to manufacture all or part of a production unit (Wilson, 2009, p. 214-215). Following are the characteristics of effective cellular manufacturing practice.

1. Should have one-piece or very small lot of flow.

2. The equipment should be right-sized and very specific for the cell operations.
3. Is usually arranged in a C or U shape so the incoming raw materials and outgoing finished goods are easily monitored.
4. Should have cross-trained people within the cell for flexibility of operation.
5. Generally, the cell is arranged in C or U shape and covers less space than the long assembly lines.

There are lots of benefits of cellular manufacturing over long assembly lines. Some of them are as follows (Heizer and Render, 2000, p. 345-346).

1. Reduced work in process inventory because the work cell is set up to provide a balanced flow from machine to machine.
2. Reduced direct labor cost because of improved communication between employees, better material flow, and improved scheduling.
3. High employee participation is achieved due to added responsibility of product quality monitored by themselves rather than separate quality persons.
4. Increased use of equipment and machinery, because of better scheduling and faster material flow.
5. Allows the company higher degrees of flexibility to accommodate changes in customer demand.
6. Promotes continuous improvement as problems are exposed to surface due to low WIP and better communication.
7. Reduces throughput time and increases velocity for customer orders from order receipt through production and shipment.
8. Enhances the employee's productive capability through multi-skilled multi-machine operators.

Apart from these tangible benefits, there is the very important advantage of cellular manufacturing over the linear flow model. Due to the closed loop arrangement of machines, the operators inside the cell are familiar with each other's operations and they understand each other better. This improves the relation between the operators and helps to improve productivity. Whereas in long assembly line one operator knows only two operators (before and after his operation in the line) it seems that operators are working independently in the line.

2.6.2 Continuous Improvement

According to (Gersten and Riss, 2002, p. 41) Continuous improvement (CI) can be defined as the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance. Activities and behaviors that facilitate and enable the development of CI include problem-solving, plan-do-check-act (PDCA) and other CI tools, policy deployment, cross-functional teams, a formal CI planning and management group, and formal systems for evaluating CI activities. Successful CI implementation involves not only the training and development of employees in the use of tools and processes, but also the establishment of a learning environment conducive to future continuous learning.

The short description of PDCA cycle is given below

Plan: Identify an opportunity and plan for change.

Do: Implement the change on a small scale.

Check: Use data to analyze the results of the change and determine whether it made a difference.

Act: If the change was successful, implement it on a wider scale and continuously assess the results. If the change did not work, begin the cycle again.

Thus continuous improvement is an ongoing and never ending process; it measures only the achievements gained from the application of one process over the existing. So while selecting the continuous improvement plan one should concentrate on the area which needs more attention and which adds more value to our products. There are seven different kinds of continuous improvement tools (Larson, 2003, p. 46) they can be described as follows. The use of these tools varies from case to case depending on the requirement of the process to be monitored.

Pareto Diagram: The Pareto diagram is a graphical overview of the process problems, in ranking order from the most frequent, down to the least frequent, in descending order from left to right. Thus, the Pareto diagram illustrates the frequency of fault types. Using a Pareto, one can decide which fault is the most serious or most frequent offender.

Fishbone Diagram: A framework used to identify potential root causes leading to poor quality.

Check Sheet: A check sheet is a structured, prepared form for collecting and analyzing data. This is a generic tool that can be adapted for a wide variety of purposes.

Histogram: A graph of variable data providing a pictorial view of the distribution of data around a desired target value.

Stratification: A method of sorting data to identify whether defects are the result of a special cause, such as an individual employee or specific machine.

Scatter Diagram: A graph used to display the effect of changes in one input variable on the output of an operation.

Charting: A graph that tracks the performance of an operation over time, usually used to monitor the effectiveness of improvement programs.

2.6.3 Just in Time

Just in time is an integrated set of activities designed to achieve high volume production using the minimal inventories of raw materials, work in process and finished goods. Just in time is also based on the logic that nothing will be produced until it is needed (Shivanand, 2006, p. 45).

Just-in-time manufacturing is a Japanese management philosophy applied in manufacturing. It involves having the right items with the right quality and quantity in the right place at the right time. The ability to manage inventory (which often accounts for as much as 80 percent of product cost) to coincide with market demand or changing product specifications can substantially boost profits and improve a manufacturer's competitive position by reducing inventories and waste. In general, Just in Time (JIT) helps to optimize company resources like capital, equipment, and labor. The goal of JIT is the total elimination of waste in the manufacturing process. Although JIT system is applied mostly to manufacturing environment, the concepts are not limited to this area of business only. The philosophy of JIT is a continuous improvement that puts emphasis on prevention rather than correction, and demands a companywide focus on quality. The requirement of JIT is that equipment, resources and labor are made available only in the amount required and at the time required to do the work. It is based on producing only the necessary units in the necessary quantities at the necessary time by bringing production rates exactly in line with market demand. In short, JIT means making what the market wants, when it wants, by using a minimum of facilities, equipment, materials, and human resources (Roy, 2005, p. 170).

JIT principles are based on the following (Shivanand, 2006, p. 4):

- It is commonly used to describe the stockless production manufacturing approach, where only the right parts are completed at the right time.
- It is not a destination but a journey.
- Reducing inventory, improving quality and controlling cost.
- A "Pull System" where the parts are produced only when they are required.

Pull and Push System

In push system, when work is finished at a workstation, the output is pushed to the next station; or, in the case of the final operation, it is pushed on to the final inventory. In this system, work is pushed on as it is completed, with no regard for whether the next station is ready for the work or not. In this way, the WIP is unbalanced in all operations throughout the shop floor (Roy, 2005, p. 174).

TABLE 1: Difference between push and pull manufacturing system

Description	**Push System**	**Pull System**
Signal to produce more	Schedule or plan	Customer signal
Timing of signal	Advance of the need	At the time of the need
Planning horizon	Fairly long	Very short
Leveling of demand	No	Generally yes
Negatives about the system	Too much inventory, no visual control, long and planned lead times, requires more information	Does not planned ahead, missed customer demand at the beginning of product life cycle, too much inventory at the last
Best for	Non repetitive, batch, short product lifecycle, long lead time purchasing	Repetitive, high volume manufacturing and stable demand
Problem visibility	Not visible	Visible
Stress to improve	Little	Much

The push system is also known as the Materials Requirements Planning (MRP) system. This system is based on the planning department setting up a long-term production schedule, which is then dissected to give a detailed schedule for making or buying parts. This detailed schedule then pushes the production people to make a part and push it forward to the next station. The major weakness of this system is that it relies on guessing the future customer demand to develop the schedule that production is based on and guessing the time it takes to produce each part. Overestimation and under-estimation may lead to excess inventory or part shortages, respectively (Shivanand, 2006, p. 50).

Whereas in pull system; each work station pulls the output from the preceding station as it is needed. Output from the final operation is pulled by customer demand or the master schedule. Thus in pull system work is moved in response to demand from the next stage in the process. The Kanban system is used to monitor the effective pull process. Table 1 helps to differentiate Pull and Push system.

2.6.4 Total Productive Maintenance

Machine breakdown is one of the major headaches for people related to production. The reliability of the equipment on the shop floor is very important because if any one of the machines is down the entire shop floor productivity may be nil. The tool that takes care of these sudden breakdowns and awakes maintenance as well as production workers to minimize these unplanned breakdowns is called total productive maintenance. Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to increase production, increase employee morale and job satisfaction. (Bisen and Srivastava, 2009, p. 175)

TPM is set of tools, which when implemented in an organization as a whole gives the best utilization of machines with least disruption of production. The set of tools are called pillars of TPM and they are shortly described here and illustrated in a TPM diagram (Figure 2).

5S

The first pillar of TPM is called 5S, which organize and cleans work place; this helps to make problems visible and attracts the attentions of everyone. Brief description of 5S elements are as follows:

Sort: The first step in making things cleaned up and organized.
Set In Order: Organize, identify and arrange everything in a work area.
Shine: Regular cleaning and maintenance.
Standardize: Make it easy to maintain, simplify and standardize.
Sustain: Maintain what has been achieved.

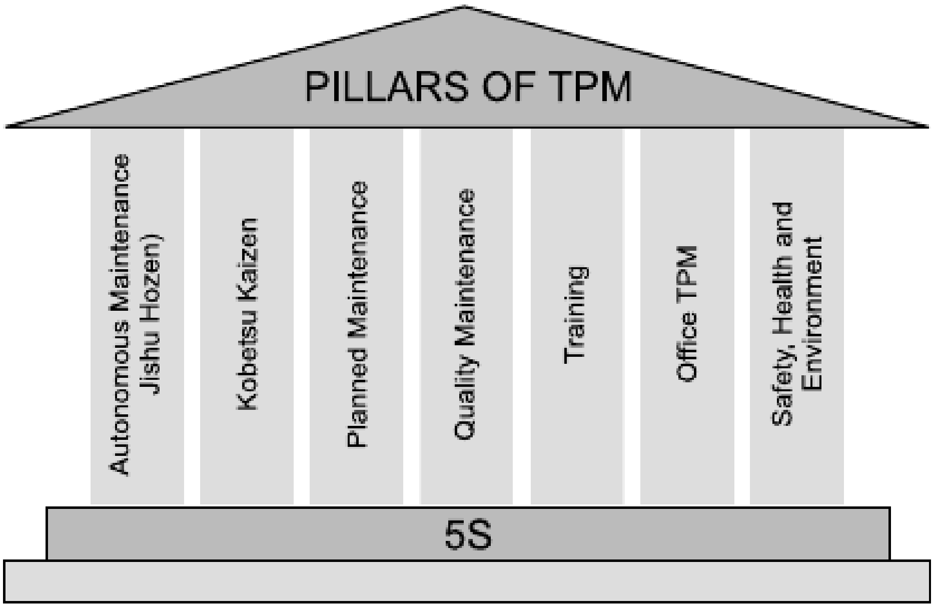

FIGURE 2: TPM diagram - Pillars of TPM (Kumar, 2008, p. 217)

Autonomous maintenance

This is about the involvement of production workers in the day to day general maintenance of machines like cleaning, lubricating etc. which saves the time of skilled maintenance person at the same time the production workers are made more responsible to their machines.

Kaizen

Kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value." This pillar is aimed at reducing losses in the workplace that affect our efficiencies (Kumar, 2008, p. 220).

Planned maintenance

It addresses the proactive approach of maintenance activities. This involves four types of maintenance namely preventive maintenance, breakdown maintenance, corrective maintenance, and maintenance prevention.

Quality Maintenance

It is aimed towards customer delight through the highest quality and defect free manufacturing. In this system, one has to take care of parts which affect product quality and try to eliminate or modify them to give customer superior quality.

Training

Employees should be trained such that they can analyze the root cause of the problem. General know how of the problem is not sufficient rather they should be able to know why the problem is occurring and how to eliminate it. For this employee need continuous training, ultimately; the entire employee should be multi-skilled and should solve the problem in their area by themselves.

Office TPM

This tool is about increasing the efficiencies in office (administrative) activities. This tool works the problems like communication issues, data retrieval processes, management information systems, office equipment losses, up to date information about inventories etc.

Safety Health and Environment

In this area, the focus is to create a safe workplace and a surrounding area that would not be damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. Safe work environment means accident free, fire less and it should not damage the health of workers.

2.6.5 Work Standardization

A very important principle of waste reduction is the standardization of work. Standardized work basically ensures that each job is organized and carried out in the same manner; irrespective of the people working on it. In this way if the work is standardized the same quality output will be received even if the worker is changed in process. At Toyota, every worker follows the same processing steps all the time. This includes the time needed to finish a job, the order of steps to follow for each job, and the parts on hand. By doing this one ensures that line balancing is achieved, unwanted work in process inventory is minimized and non value added activities are reduced. A tool that is used to standardize work is called takt time.

2.6.6 Waste Reduction Techniques

Some of the waste reduction tools include zero defects, setup time reduction, and line balancing. The goal of zero defects is to ensure that products are fault free all the way, through continuous improvement of the manufacturing process (Karlsson and Ahlstrom 1996). Human beings almost invariably will make errors. When errors are made and are not caught then defective parts will appear at the end of the process. However, if the errors can be prevented before they happen then defective parts can be avoided. One of the tools that the zero defect principle uses is Poka Yoke. Poka-Yoke, which was developed by Shingo, is an autonomous defect control system that is put on a machine that inspects all parts to make sure that there are zero defects. The goal of Poka-Yoke is to observe the defective parts at the source, detect the cause of the defect, and to avoid moving the defective part to the next workstation (Feld, 2000).

Single Minute Exchange of Die (SMED) is another technique of waste reduction. During 1950's Ohno devised this system; and was able to reduce the die changing time from 1 day to three minutes (Womack, Jones and Ross, 1990). The basic idea of SMED is to reduce the setup time on a machine. There are two types of setups: internal and external. Internal setup activities are those that can be carried out only when the machine is stopped while external setup activities are those that can be done during machining. The idea is to move as many activities as possible from internal to external (Feld, 2000). Once all activities are identified than the next step is to try to simplify these activities (e.g. standardize setup, use fewer bolts). By reducing the setup time many benefits can be realized. First, die-changing specialists are not needed. Second, inventory can be reduced by producing small batches and more variety of product mix can be run.

Line balancing is considered a great weapon against waste, especially the wasted time of workers. The idea is to make every workstation produce the right volume of work that is sent to upstream workstations without any stoppage (Mid-America Manufacturing Technology Center Press Release, 2000). This will guarantee that each workstation is working in a synchronized manner, neither faster nor slower than other workstations.

2.6.7 Value Stream mapping

Value Stream Mapping (VSM) is a technique that was originally developed by Toyota and then popularized by the book, Learning to See (The Lean Enterprise Institute, 1998), by Rother and Shook. VSM is used to find waste in the value stream of a product. Once waste is identified, then it is easier to make plan to eliminate it. The purpose of VSM is process improvement at the system level. Value stream maps show the process in a normal flow format. However, in addition to the information normally found on a process flow diagram, value stream maps show the information flow necessary to plan and meet the customer's normal demands. Other process information includes cycle times, inventories, changeover times, staffing and modes of transportation etc. VSMs can be made for the entire business process or part of it depending upon necessity. The key benefit to value stream mapping is that it focuses on the entire value stream to find system wastes and try to eliminate the pitfall (Wilson, 2009, p. 147-153). Generally, the value stream maps are of three types. Present State Value Stream Map (PSVSM) tells about the current situation, Future State Value Stream Map (FSVSM) can be obtained by removing wastes (which can be eliminated in the short time like three to six months) from PSVSM and Ideal State Value Stream Mapping (ISVSM) is obtained by removing all the wastes from the stream. The VSM is designed to be a tool for highlighting activities. In lean terminology they are called kaizen activities, for waste reduction. Once the wastes are highlighted, the purpose of a VSM is to communicate the opportunities so they may be prioritized and acted upon. Hence, the prioritization and action must follow the VSM, otherwise it is just a waste like other wastes.

2.7 **Method Study**

Method study focuses on how a task can (should) be accomplished. Whether controlling a machine or making or assembling components, how a task is done makes a difference in performance, safety, and quality. Using knowledge from ergonomics and methods analysis, methods engineers are charged with ensuring quality and quantity standards are achieved efficiently and safely. Methods analysis and related techniques are useful in office environments as well as in the factory. Methods techniques are used to analyze the following (Heizer et al., 2000, p. 394-396):

1. Movement of individuals or material. Analysis for this is performed using flow diagrams and process charts with varying amounts of detail.
2. Activity of human and machine and crew activity. Analysis for this is performed using activity charts (also known as man-machine charts and crew charts).
3. Body movement (primarily arms and hands). Analysis for this is performed using micro-motion charts.

2.8 Labor Standards and Work Measurements

Effective operations management requires meaningful standards that can help a firm to determine the following (Heizer et al., 2000, p. 408-420)

1. Amount of labor contribution for any product (the labor cost).
2. Staffing needs (how many people it will take to meet required production).
3. Cost and time estimates prior to production (to assist in a variety of decisions, from cost estimates to make or buy decisions).
4. Crew size and work balance (who does what in a group activity or on an assembly line).
5. Expected production (so that both manager and worker know what constitutes a fair day's work).
6. Basis of wage-incentive plan (what provides a reasonable incentive).

7. Efficiency of employees and supervision (a standard is necessary against which to determine efficiency).

Properly set labor standards represent the amount of time that it should take an average employee to perform specific job activities under normal working conditions. The labor standards are set in by historical experience, time studies, predetermined time standards and work sampling.

2.8.1 Historical Experience

Labor standards can be estimated based on historical experience i.e. how many labor hours were used to do a similar task when it was done last time. Based upon this experience the new time will be fixed for any new operation or works. Historical standards have the advantage of being relatively easy and inexpensive to obtain. They are usually available from employee time cards or production records. However, they are not objective, and we do not know their accuracy, whether they represent a reasonable or poor work pace, and whether unusual occurrences are included. Because their variables are unknown, their use is not recommended. Instead, time studies, predetermined time standards and work sampling are preferred (Heizer et al., 2000, p. 409).

2.8.2 Time Studies

The classical stopwatch study, or time study, originally proposed by Federic W. Taylor in 1881, is still the most widely used time study method. The time study procedure involves the timing of a sample of worker's performance and using it to set a standard. A trained and experienced person can establish a standard by following these eight steps (Heizer et al., 2000, p. 409-412).

1. Define the task to be studied (after methods analysis has been conducted).

2. Divide the task into precise elements (parts of a task that often takes no more than a few seconds).
3. Decide how many times to measure the task (the number of cycles of samples needed).
4. Record elemental times and rating of performance.
5. Compute the average observed cycle time. The average observed cycle time is the arithmetic mean of the times for each element measured, adjusted for unusual influence for each element:

$$\text{Average observed cycle time} = \frac{\begin{array}{c}\text{Sum of the times recorded}\\ \text{to perform each element}\end{array}}{\text{Number of } cycles \text{ observed}}$$

6. Determine performance rating and then compute the normal time for each element.

   Normal Time = (average observed cycle time) x (performance rating factor).
7. Add the normal times for each element to develop a total normal time for each task.
8. Compute the standard time. This adjustment to the total normal time provides allowances such as personal needs, unavoidable work delays and worker fatigue.

$$\text{Standard Time} = \frac{\text{Total normal time}}{1 - \text{Allowance factor}}$$

Personal time allowances are often established in the range of 4% to 7% of total time, depending upon nearness to rest rooms, water fountains, and other facilities. Delay allowances are often set as a result of the actual studies of the delay that occurs. Fatigue allowances are based on our growing knowledge of human energy expenditure under various physical and environmental conditions. The major two disadvantages of this method are; first they require a trained staff of analysts and secondly the labor standards cannot be set before tasks are actually performed.

2.8.3 Predetermined Time Standards

Predetermined time standards divide manual work into small basic elements that already have established times (based on very large samples of workers). To estimate the time for a particular task, the time factors for each basic element of that task are added together. Developing a comprehensive system of predetermined time standards would be prohibitively expensive for any given firm. Consequently, a number of systems are commercially available. The most common predetermined time standard is methods time measurement (MTM), which is the product of the MTM association (Heizer et al., 2000 p. 415-416).

Predetermined time standards are an outgrowth of basic motions called therblings. The term "therblig" was coined by Frank Gilbreth. Therbligs include such activities as select, grasp, position, assemble, reach, hold, rest and inspect. These activities are stated in terms of time measurement units (TMUs), which are each equal to only 0.00001 hour or 0.0006 minutes. MTM values for various therbligs are specified with the help of detailed tables.

Predetermined time standards have several advantages over direct time studies. First, they may be established in laboratory environment, where the procedure will not upset actual production activities. Second, because the standard can be set before a task is actually performed, it can be used for planning. Third, no performance ratings are necessary. Fourth, unions tend to accept this method as fair means of setting standards. Finally, predetermined time standards are particularly effective in firms that do substantial numbers of studies of similar tasks.

2.8.4 Work Sampling

It is an estimate of the percentage of time that a worker spends on particular work by using random sampling of various workers. This can be conducted by the following procedures (Heizer et al., 2000, p. 416-418).

1. Take a preliminary sample to obtain an estimate of the parameter value (such as percent of time worker is busy).
2. Compute the sample size required.
3. Prepare a schedule for observing the worker at appropriate times. The concept of random numbers is used to provide for random observation. For example, let's say we draw the following 5 random numbers from a table: 07, 12, 22, 25, and 49. These can then be used to create and observation schedules of 9:07 AM, 9:12, 9:22, 9:25, and 9:49 AM.
4. Observe and record worker activities.
5. Determine how workers spend their time (usually as percentage).

To determine the number of observation required, management must decide upon the desired confidence level and accuracy. First, however, the analyst must select a preliminary value for the parameter under study. The choice is usually based on small sample of perhaps 50 observations. The following formula then gives the sample size for a desired confidence and accuracy.

$$n = z^2 * p\,(1 - p)/h^2$$

Where, n = required sample size

z = standard normal deviate for the desired confidence level

(z = 1 for 68% confidence, z = 2 for 95.45% confidence, and z = 3 for 99.73% confidence level)

p = estimated value of sample proportion (of time worker is observed busy or idle)

h = acceptable error level, in percent

Work sampling offers several advantages over time study methods. First, because a single observer can observe several workers simultaneously, it is less expensive. Second, observers usually do not require much training and no timing devices are needed. Third, the study can be temporarily delayed at any time with little impact on the results. Fourth, because work sampling uses instantaneous observations over a long period, the worker has little chance of affecting the study outcome. Fifth, the procedure is less intrusive and therefore less likely to generate objections. The disadvantages of work sampling are:

1. It does not divide work elements as completely as time studies.
2. It can yield biased or incorrect results if the observer does not follow random routes of travel and observation.
3. Being less intrusive, it tends to be less accurate; this is particularly true when cycle times are short.

2.9 Layout Design

Layout is one of the key decisions that determine the long-run efficiency of operations. Layout has numerous strategic implications because it establishes an organization's competitive priorities in regard to the capacity, processes, flexibility and cost as well as quality of work life, customer contact and image. An effective layout can help an organization to achieve a strategy that supports differentiation, low cost, or response (Heizer et al., 2000, p. 336). The layout must consider how to achieve the following:

1. Higher utilization of space, equipment, and people.
2. Improved flow of information, material or people.
3. Improved employee morale and safer working conditions.
4. Improved customer/client interaction.
5. Flexibility (whatever the layout is now, it will need to change).

Types of Layout

Layout decision includes the best placement of machines (in production settings), offices and desks (in office settings) or service center (in setting such as hospitals or department stores). An effective layout facilitates the flow of materials, people, and information within and between areas. There are various kinds of layouts. Some of them are as follows (Heizer et al., 2000, p. 336-337).

1. **Fixed Position layout –** addresses the layout requirements of large, bulky projects such as ships and buildings (concerns the movement of material to the limited storage areas around the site).
2. **Process Oriented Layout –** deals with low volume, high variety production (also called ‘job shop’, or intermittent production). It can manage varied material flow for each product.
3. **Office Layout –** fixes workers positions, their equipment, and spaces (offices) to provide for movement of information (locate workers requiring frequent contact close to one another).
4. **Retail Layout –** allocates shelf space and responds to customer behavior (expose customer to high margin items).
5. **Warehouse Layout –** it addresses tradeoffs between space and material handlings (balance low cost storage with low cost material handling).
6. **Product oriented layouts –** seeks the best personnel and machine utilization in repetitive or continuous production (equalize the task time at each workstation).

2.10 Assembly Line Balancing

Line balancing is usually undertaken to minimize imbalance between machines or personnel while meeting a required output from the line. The production rate is indicated as cycle time to produce one unit of the product, the optimum utilization of work force depends on the basis of output norms. The actual output of the individual may be different from the output norms. The time to operate the system, hence, keeps varying. It is, therefore, necessary to group certain activities to workstations to the tune of maximum of cycle time at each work station. The assembly line needs to balance so that there is minimum waiting of the line due to different operation time at each workstation. The sequencing is therefore, not only the allocation of men and machines to operating activities, but also the optimal utilization of facilities by the proper balancing of the assembly line (Sharma, 2009, p. 179).

The process of assembly line balancing involves three steps (Heizer et al., 2000, p. 356-358):

1. Take the units required (demand or production rate) per day and divide it into the productive time available per day (in minutes or seconds). This operation gives us what is called the cycle time. Namely, the maximum time that the product is available at each workstation if the production rate is to be achieved.

   Cycle time = production time available per day / units required per day

2. Calculate the theoretical minimum number of workstations. This is the total task duration time (the time it takes to make the product) divided by the cycle time. Fractions are rounded to the next higher whole number.

   $\text{Minimum Number of Workstations} = \sum_{i=1}^{n} \text{Time for Task i / Cycle Time}$

   Where n is the number of assembly tasks.

3. Balance the line by assigning specific assembly tasks to each workstation. An efficient balance is one that will complete the required assembly, follow the specified sequence, and keep the idle time at each work stations to a minimum.

2.10.1 Takt Time

Takt is German word for a pace or beat, often linked to conductor's baton. Takt time is a reference number that is used to help match the rate of production in a pacemaker process to the rate of sales. This can be formulated as below (Rother and Harris, 2008, p. 13).

$$\text{Takt Time} = \frac{\text{Available work time per shift}}{\text{Customer order quantity per shift}}$$

Takt time can be defined as the rate at which customers need products i.e. the products should be produced at least equal to takt time to meet the customer demand. Takt time works better when customer demand is steady and clearly known; but if the customer demand varies on the daily basis then it is difficult to calculate the takt time as well as balance the production facility according to varying takt time. So if the orders are varying every day the information of actual shipments (not orders) should be gathered for last few months or years and takt time for the particular product should be calculated. In this way, the production can be balanced to meet changing customer demand.

2.10.2 Cycle Time

Cycle time is defined as how frequently a finished product comes out of our production facility (Rother et al., 2008, p. 15). Cycle time includes all types of delays occurred while completing a job. So cycle time can be calculated by the following formula.

Total Cycle Time = processing time + set up time + waiting time + moving time + inspection time + rework time + other delays to complete the job

To meet customer demand or monitor productivity the cycle time and takt time should be balanced in parallel. The higher cycle time than takt time may result the late delivery and customer dissatisfaction whereas shorter cycle time than takt time may cause the excess inventory or excess use of resource.

2.11 Summary

This chapter briefly describes lean manufacturing tools and techniques for waste reduction and efficiency enhancement. Literature defines lean manufacturing, describes some lean tools (most relevant to this research), work standardization and assembly line balancing tools. The lean tools selected consist of cellular manufacturing, single piece flow, just in time (pull production), work standardization methods, continuous improvement process, and some other waste reduction tools. The chapter ends with the work standardization process by time studies, layout design and assembly line balancing methods.

Lean is a powerful tool, when adopted it can create superior financial and operational results. But in many cases, the confusion about how to start lean, from where to begin is also a problem for new practitioners. In some cases, the company tries to implement lean but it does not give effective results and stops in-between. All these are due to lack of clarity before implementing lean and lack of top management commitment. So to avoid the chances of failure one has to prepare in advance for the outcomes of the lean and should involve all employees on improvement programs. Lean is not just about the implementation of tools but also the development of its employees to adopt these tools. So, regular training and upgrading of employee skill is the most important factor for the success of lean.

3 GARMENT MANUFACTURIGN PROCESS

3.1 Industry Background

The research is conducted in garment industry whose major products are Men's formal shirt in various order size. The factory consists of central cutting department, 3 independent stitching lines and central finishing (packing) section. Generally, operators are responsible for the quality of individual work, even after that there is quality check (audit) at the end of each section (department) so that there should not be any defective parts transferred from one section to another section. The overall production flow chart of the shop floor is shown in Figure 3.

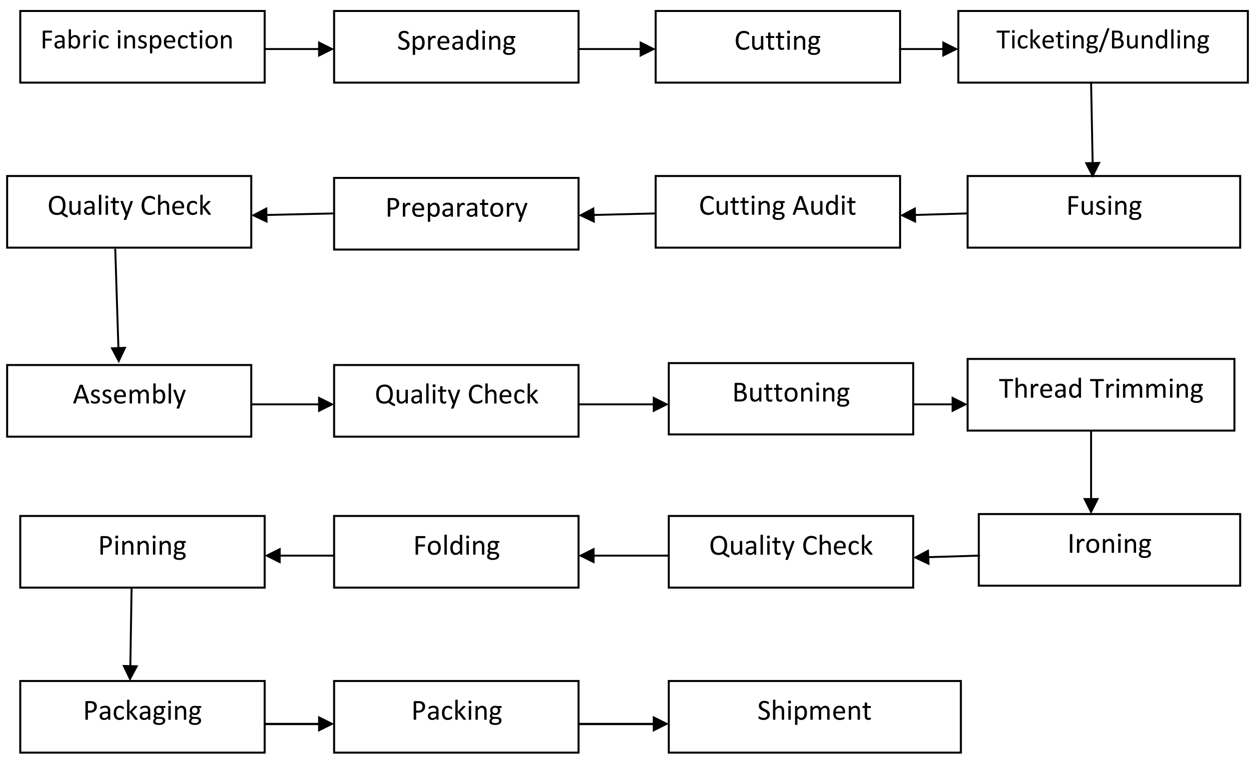

FIGURE 3: Garment production process flow chart

3.2 Garment Manufacturing Process

Garment manufacturing process consists of series of different steps. These steps are broadly divided into two categories pre-production and production process. The pre-production process consists of designing the garment, pattern design, sample making, production pattern making, grading and marker making. Once the sample is approved for commercial production, final marker is made for cutting. The production process consists of cutting, stitching (preparatory and assembly) and finishing all these process are described here.

3.2.1 Cutting Section

In cutting section fabric rolls are inspected as per work order. These inspected rolls are segregated on two sides as the quality pass and fail. The pass rolls are taken into the next operation whereas the fail rolls returned to store with red tags on them. After this, depending upon the order, size and quantity ratio; the spreader spreads the fabric for cutting. Once cutting is done, bundles of approx 20 to 30 pieces are made and fusing is done simultaneously. After fusing, all the parts are collected and put in the cutting audit. The bundles which pass the cutting audit are forwarded to the sewing section (i.e. preparatory section) whereas the fail bundles were re-worked for correction. This whole process can be shown in the flow chart as in Figure 4.

3.2.2 Preparatory Section

In preparatory section individual parts are made for assembly purpose. It consists of four sub sections Cuff, Collar, Front and Sleeve. Each of these sections includes the series of different operations to complete that part. These final parts are checked (or audited) so that defective parts should not go to the assembly operations; the flow of operations for the preparatory section is shown in Figure 5.

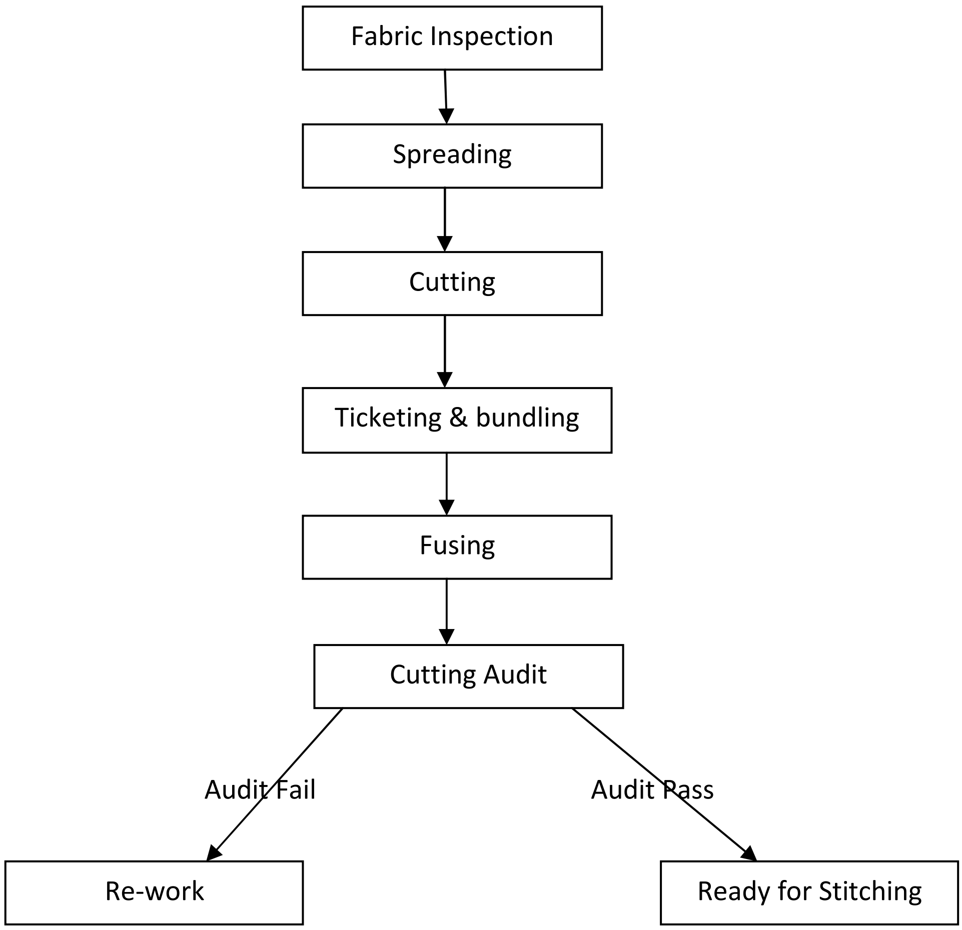

FIGURE 4: Cutting section production flow chart

In current situation, the preparatory operations are aligned in a single line in order of operation sequence. There is a continuous long table between the machines which serves the material flow from one operation to another. Once the operator finishes his (her) operation he (she) pushes the WIP to the next operator in the table and this process continues to the end.

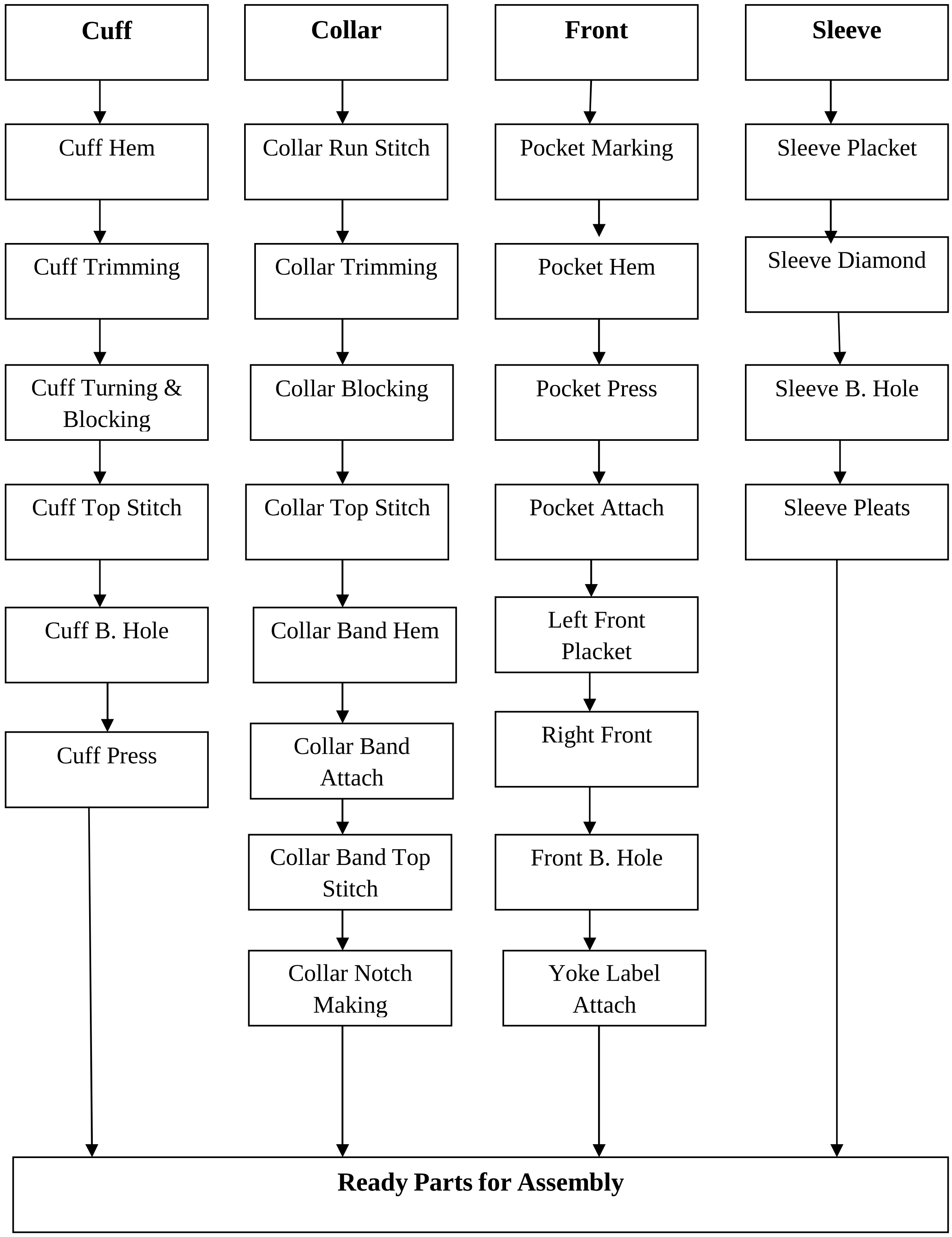

FIGURE 5: Preparatory section production flow chart

3.2.3 Assembly Section

This section consists of ten operations to make one full garment. The machines are kept in single straight line according to the operation sequence. The final garment from last operation is fully checked and corrected immediately for any defects. WIP movement inside the assembly is made by the help of work aids attached with each machine. The operator, after completing his (her) operation forwards the semi finished garments to the next machine with the help of work aids attached to each machine. This process continues to the end of assembly line for each operation. At the same time the required parts from preparatory are carried up to the assembly section manually. The flow chart for the assembly operation is shown in Figure 6.

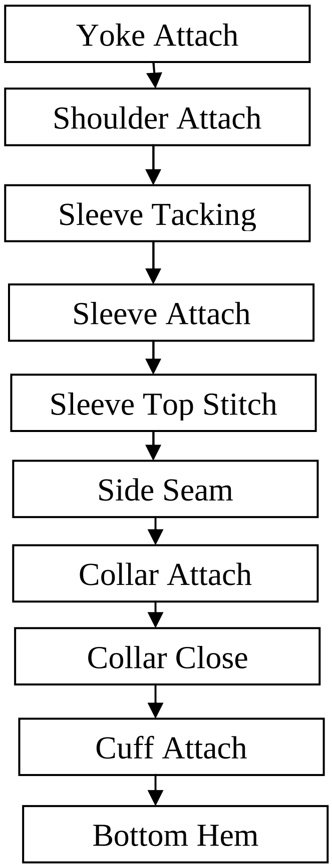

FIGURE 6: Assembly section production flow chart

3.2.4 Finishing Section

Finishing section consists of three major operations: buttoning and thread cleaning, ironing and final packing. But in some garment washing is needed, in this case washing should be done before buttoning to minimize damages in garments for longer washing cycles. In the case company after buttoning there is thread cleaning section followed by ironing, finishing and packing. The operation sequence for finishing section is shown in Figure 7.

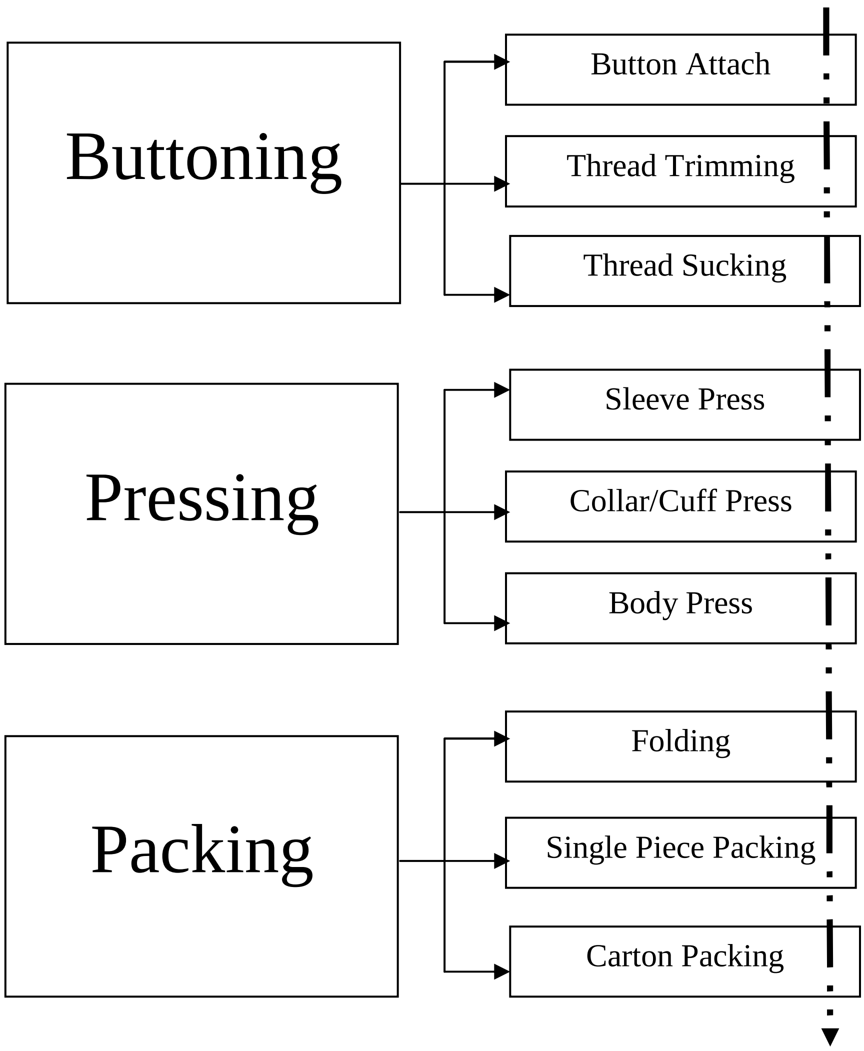

FIGURE 7: Finishing section production flow chart

3.3 Style Communication

Style communication between different staffs and operators is critical part of garment manufacturing to minimize style related confusion during production. Because the fashion changes so frequently that there may be the need of producing new styles every day, so in this situation if the shop floor people didn't get accurate information for the garment being produced chances of mistakes are high. To minimize difficulties of this kind, there is pre-production meeting between shop floor supervisors, machine technicians and operators. The purpose of this meeting is to communicate about the various requirements of the upcoming style, for example critical operations on the garment, type of machine and machine accessories required, garment specifications, type of seams, target production per day, total order quantity, size ratio etc. In some industries trial production is done for every new style, this helps to minimize the confusion and rejection during bulk production. In this system commercial production starts only after checking the final parameters of trial production. But nowadays, due to very small order quantity (order volume) the trial production may not be feasible for each style. In such case a clear information flow is of great importance.

3.4 Existing Production Layout

Existing layout of the sewing section (preparatory and assembly) is given in Figure 8. In this layout, the individual parts are made in preparatory sections and these parts are then transported manually to the assembly section. In the assembly section, these parts are assembled to shape a final garment. There is quality check at the end of each section to avoid defective parts to the next step. WIP movement in preparatory section is made with the help of the long table along with machines, whereas work aids attached with each machine serves this purpose in the assembly section.

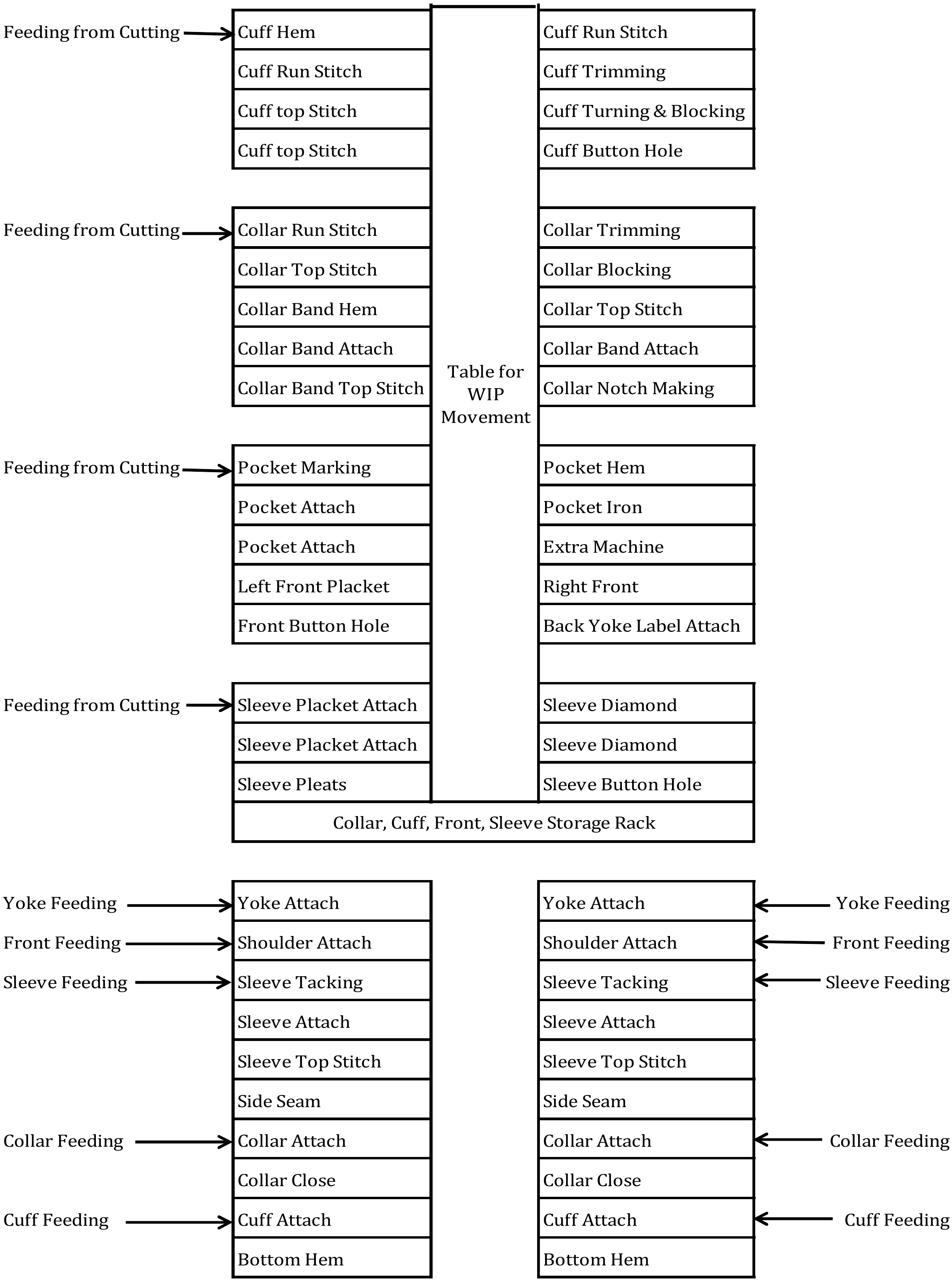

FIGURE 8: Existing production layout of stitching section

3.5 WIP Movement System

There are different types of WIP movement systems applied in garment manufacturing industries. Some of them are traditional, for example by trolleys or by hand carry. Some advanced factories use the slow motion conveyor to move the parts from one operation to another operation. The conveyor is designed such that it moves according to the operation sequence. In this system, the first operator stitches and puts the part in the conveyor, then the next operator receives that part. He also sews it and puts it in the conveyor. In this way, the unnecessary movement is reduced. This method is generally suitable for single piece movement. In some industries, the work aids are designed such that the piece moves in forward directions. When the first operator finishes his operation he gives it directly to the next operator with the help of work aids, and this process continues. Thus the selection of the WIP movement method depends upon the design layout, the technological advancement of the industry as well as expertise of the personnel.

4 RESEARCH OF THE EXISTING PRODUCTION

The research consists of conducting time and motion study of stitching operations. By doing this, stitching operations will be standardized and production targets for each operation will be fixed. Secondly, batch processing is converted into single piece movement by the implication of new layout (cellular manufacturing). This will serve the purpose of WIP reduction. For the ease of operator movement between machines, sitting operations were converted into standing. The worker multi-skilling is achieved by the concept of assembly line balancing. As in cellular manufacturing the numbers of operators are less than the number of operations (machines), one operator has to perform at least three to four operations. This will help to increase operator skill. Finally, flexibility in production is achieved by reduced WIP and multi-skilled operators, who can work on multiple styles immediately.

4.1 Conducting Time Study

To calculate standard time for each operation, time study is conducted in the shop floor. To do this, the standard formal shirt is selected as a base line because operations differ from style to style and it is difficult to correlate all these operations of individual styles. After that, at least two operators were selected for each operation so that the difference in timing can be cross checked from the observed data of these two operators. To get better results, each operation time is taken for at least 15 cycles. Once time study is made by collecting raw data the performance rating is given to each operator and actual time is calculated for particular operation. Finally the Personal Fatigue and Delay (PFD) component is added on the calculated time and the operation time is standardized. The format of time study data collection sheet is attached in the Appendix-I.

While conducting time study some parameters are kept fixed (for example machine speed, stitches per inch, type of machine used etc.) to get consistent results. The PFD factor is taken as 15% of total time. This PFD is a little bit higher than normal industry standard; it is taken higher considering the standing operation and operator's movement inside the cell. Similarly the average performance rating is taken 100% for the ease of calculation only. This rating is adjusted average of actual ratings. The calculated SAM value for each section is attached in appendices. (Cuff and Collar section SAM on Appendix- II, Front and Sleeve section SAM on Appendix- III, and Assembly section SAM on Appendix- IV).

4.2 Creating Cellular Layout

In new cellular layout some operations were removed from the existing one. First, the quality checking points were removed from the preparatory, because the operator who is producing garments should be aware of quality standards and should work accordingly. After that, approximately four operations were removed from the process (three operations were combined with other operations and one operation is completely removed by changing the operation sequence). Once operations were finalized, creation of work cells takes place. The creation of cells is as per the operations needed to complete individual parts. For example, in case of cuff section there are approximately six operations to make the complete cuff. Thus all these operations related to cuff sections are grouped in one cell. Similarly, operations of other sections are also grouped in their respective cells and given individual name. Total, five cells were created (four cells in preparatory section and one cell in assembly) to complete the garment.

The assembly operations are kept at the center and all other preparatory operations were aligned in four sides of assembly. The cells working in preparatory operations (Cuff, Collar, Front and Sleeve) were aligned such that the last operation of each preparatory section should directly supply its final products to the respective first operation of assembly (for example, cuff section supplies cuff to the cuff attach of assembly, collar section supplies collar to the collar attach, sleeve section supplies sleeves to the sleeve attach, front section supplies fronts to the shoulder attach of assembly section). This will eliminate WIP movement from preparatory to assembly. In this way, the preparatory and assembly operations were kept in a close loop. In this new layout, after feeding cut parts they will be converted into final garment immediately because there is no WIP storage area, as well as operators are not allowed to build up a WIP, rather they should change their operation immediately if WIP seems increasing. At the same time, each operator is responsible for their work because quality checkers were removed from the line. Only the final products after assembly are audited randomly for ensuring the quality of output. The recommended new layout is shown in Figure 9.

The cellular layout suggested in this research is selected for single piece flow because of cost effectiveness, operator skill enhancement as well as to shorten the time to implement it. Because there is no need for ordering or installing any new equipment, it is just re-arranging the available machines inside the shop floor. This work of single piece movement can also be done with the help of automation (like slow speed conveyor and hanger system) but it may take considerable time to install, significant amount of cost as well as time to train the employees about the working principle of the system. Even after using the automation system (slow speed conveyor or hanger) the operator multi-skilling cannot be achieved because in this case also operators are in fixed allocated operations whereas the conveyor rotates pieces automatically, it serves only the single piece movement but not the multi-skilling.

4.3 Work Balancing between Operators

After defining work flow and creating cellular layout, the challenge is division of work between operators. The work should be divided in such a way that each operator should get equal work load. This will motivate operators in their work as a result of which there is improvement in productivity. To achieve this a few elements were considered as key elements and acted accordingly as below.

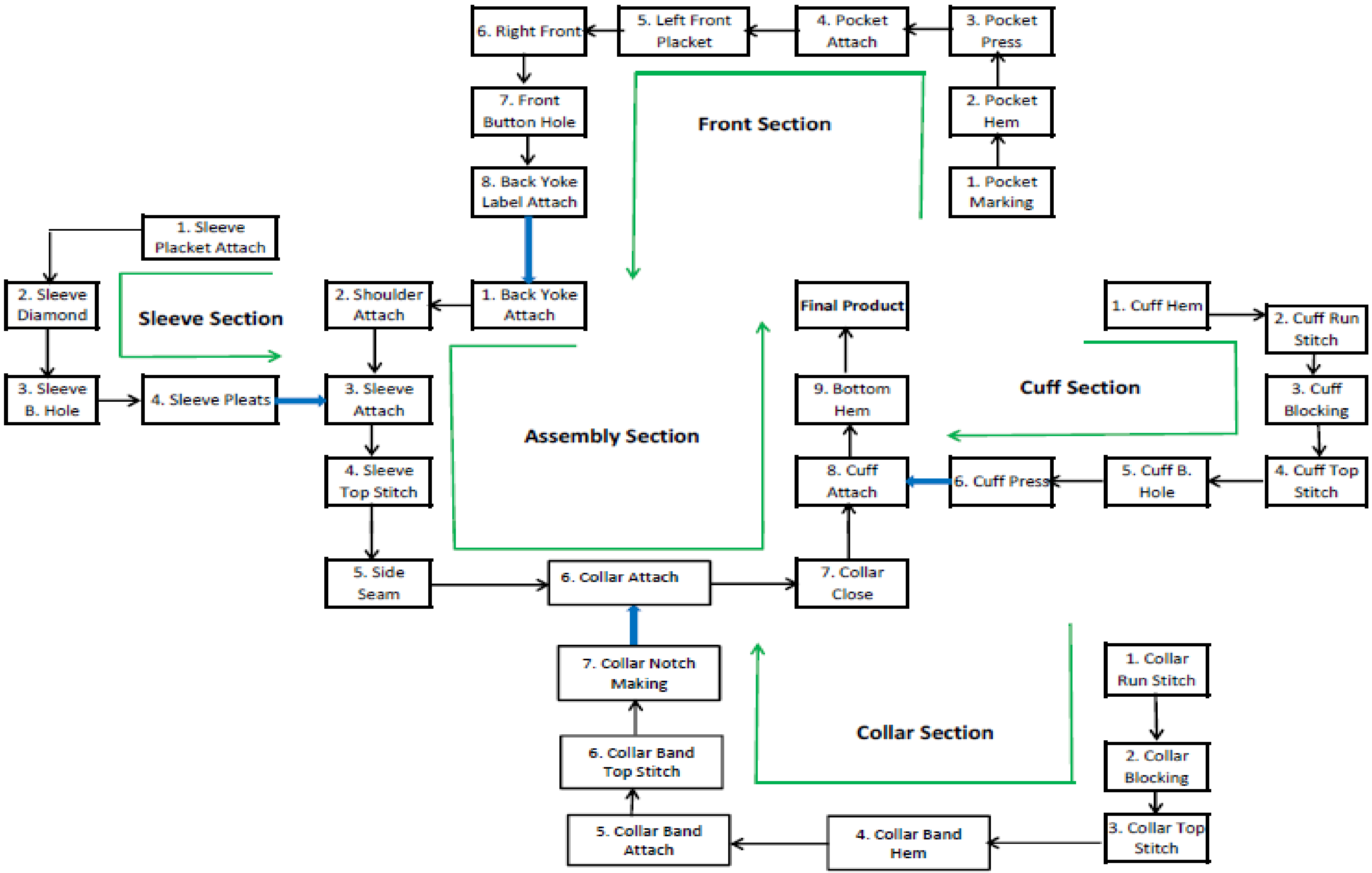

FIGURE 9: Recommended stitching section layout

1. All the sitting operations were converted into standing operations. This will help to travel between machines so that one operator can handle multiple machines within the cell. This is very difficult in case of sitting operations.
2. Operators should be trained for at least three to four operations of their respective work cells. This will help to rotate operators between different operations.
3. To create pull system, the capacity of assembly is made marginally higher than preparatory operations. In this way every time when assembly operators are out of pieces, everybody's attention will go to preparatory section cells and they will produce more for assembly operators.
4. The numbers of operators are less than the number of work stations (machine) for rotating operators between different operations; this helps in balancing the work load between operators.
5. Finally, work is divided among operators of individual cells as per SAM. This is a little bit difficult job because different operations have different timings. So the worker who is working in a job which takes less time should not build up WIP, rather should change his (her) machine and do the next consecutive operation. In this way, all the workers will rotate inside the cell in zigzag pattern to balance the work. This way of moving operators inside the work cell is called floating balancing.

The number of work stations and number or operators in different work cells is shown in Table 2; which shows that there are sufficient work stations to rotate operators. In total 23 operators are working on 34 machines (operations). Thus when WIP increases the operator should immediately switch to the next operation and move forward.

4.4 Critical Operation Handling

Any product consists of a set of different operations with varying time and skill requirements in each stage. Even within the same work cell some operations are critical in comparison to others. The criticality of operation can be of different types; for example the job may be critical being more time consuming than other jobs, or it may need specific skill to complete it, or may need high attention because of customer complaints, or may be due to machine capacity etc. So after identifying the critical operations special attention should be given to them, because these are the weakest links of the chain and if one link drops the whole chain may be disturbed.

TABLE 2: Section wise number of operation and number of operator requirement

Section	**No. of Operations**	**No. of Operators**
Cuff	6	4
Collar	7	4
Front	8	5
Sleeve	4	3
Assembly	9	7
Total	**34**	**23**

In this research, the critical operations were identified for each cell. For example, in case of cuff section cuff run stitch (high time consuming) and cuff top stitch (special skill needed due to thickness of stitching area) are critical operations. In case of collar section collar band attach (due to large number of parts to be handled simultaneously) is critical operation. Similarly, the pocket ironing (due to frequent iron weight lifting) and pocket attach (due to different shapes of pocket as well as from the aesthetic point of view; because the pocket is in the center of the garment in front side) are critical operations in front section and sleeve diamond making (garment folding skill for making diamond) for sleeve section. In case of assembly, cuff attach (due to thickness of the stitching area and accurate alignment of garment) is most difficult as well as time taking work. So while balancing a cell, extra care should be given to these operations. At the same time, some extra operators should be trained for critical operations. This will save from drastic production loss in absence of critical operators or due to breakdowns of machines for these operations.

4.5 Trial Production on New Layout

There are a few challenges in this process because this layout is new to the people who have been working for years. The first difficulty is because of conversion of sitting operations to standing. Because operators were habitual of operating sitting machines and when these sitting machines were converted into standing they lost their control on pedal and it took some time to train them. Secondly, for work balancing purpose one operator has to perform multiple operations by changing machines, whereas operators don't like to work on multiple machines because they feel that management is overloading work on them.

The operators were convinced by saying that if people move around the machine they will not tire of the same operation and can work more effectively as well as feel less tired. At the same time they will learn multiple operations within their cell, which increases their skill and confidence. Similarly, the balancing of a cell is as per standard allocated minutes; so all the operators were given equal work load within their cell. Earlier to this, the critical operators were blaming management and supervisors for allocating them in difficult operations. Now by the implementation of SAM for work balancing the problem of uneven work load is solved**.**

5 RESULT ANALYSES

5.1 Throughput Time Comparison

In the existing batch production system throughput time is too high and sometimes, it took even two days (7.5 hour per day X 2 days = 15 hours) to complete a 20-minute garment. In existing situation operators took bundles of cut panels from cutting department and started producing assembly parts like cuff, collar, front and sleeves in respective sections. The problem comes when the preparatory sections produces unequal amount of parts. For example, cuff section produces 800 pieces of cuffs, collar section produces 600 pieces of collar, sleeve section produces 900 pieces of sleeves and front section produces 200 pieces of fronts. In this case maximum number of garments that can be produced will be 200 pieces only. In batch production, if everything goes well, pieces are produced without quality defects, there is no machine breakdown etc. and operator follows the bundle sequence properly it will take minimum 220 to 230 minutes. (Approximately 90 minutes in preparatory and 136 minutes in assembly to complete one bundle). Whereas this time is less than an hour in case of single piece flow recommended by this study.

On the other hand, strict follow up of ticketing numbers is another issue in garment industry. Due to shade variation, the garment parts of different ticketing numbers cannot be mixed even though they are of the same size. Thus in some cases even if all preparatory sections (collar, cuff, front and sleeve) produce equal number of parts in their respective area they cannot be used in assembly if they hadn't followed proper ticketing number.

In some cases, the problem appears due to quality issues or reworks. The operator works in bundle system and one bundle consists of approx 20 to 30 pieces. While checking these bundles; if quality checker find defects even in a few pieces, then the whole bundle will be returned to the concerned operator for correction. Thus the mistake in one or two pieces may hold the complete bundle (i.e. 20 to 30 pieces) causing unbalanced WIP. In this way if there is quality related issue in different bundles on different sections, the garment cannot be completed. For example, there are 4 bundles with 25 pieces in each bundle are loaded in stitching sections from cutting department. Suppose, cuff section has noticed rework in bundle number 1, collar section has to rework in bundle number 2, front section has to rework in bundle number 3 and sleeve section has to rework in bundle number 4, then the output for assembly will be zero. Because while feeding in assembly all parts of same bundle number should be loaded but in this case there is not even a single bundle cleared from all the sections.

In the existing system, operators start producing parts continuously at their full efficiency irrespective of the requirement of succeeding operation. Due to this there is huge WIP in between processes, which creates problems because as the WIP increases, the chances of mistakes also increase. The most important part of low WIP is; anything which feeds in production line became finished product at product cycle time. Once the problems are noticed during processing these will be corrected immediately which minimizes the cost of quality. For example, in case of batch production, if there are different styles running in preparatory and assembly and the quality checker finds some defects after assembly, then to correct this is very difficult. Because in preparatory, different style is running and the operator has already removed the trims (thread, label, buttons etc.) of previous style. In this case operator’s time is wasted in searching these items (trims) and chance of misuse of trims is very high. Thus the possibility of rework will increase with increasing quantity and time of WIP (the older the WIP, the more chances of rework).

5.2 Comparison of Production Time

Production time of the garment has been reduced by 1.65 minutes (i.e. approximately 8%). This has been achieved by combining 3 operations with other operations (cuff trimming combined with cuff run stitch, collar trimming combined with collar run stitch and sleeve tacking combined with sleeve attach) and by eliminating one operation (collar peak ironing removed by changing the shape of fusing). The time needed to complete the work on different sections is shown in Figure 10.

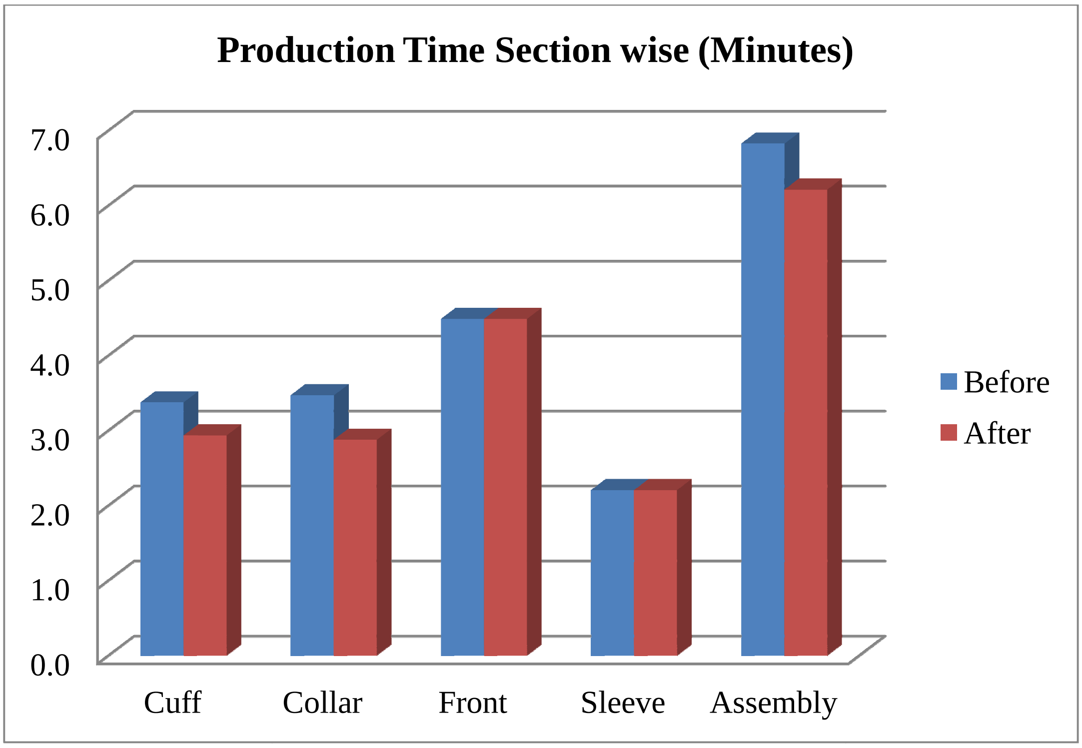

FIGURE 10: Comparison of production time for different stitching sections

5.3 Comparison of Number of Operation

The number of operation needed to complete a garment is reduced to 36 from 44. In total 4 operations were removed from stitching section and 4 operations from quality checking section. Those operations were not adding any value to the final product; so they were removed. The comparison of the number of operations before and after situation is shown in Figure 11.

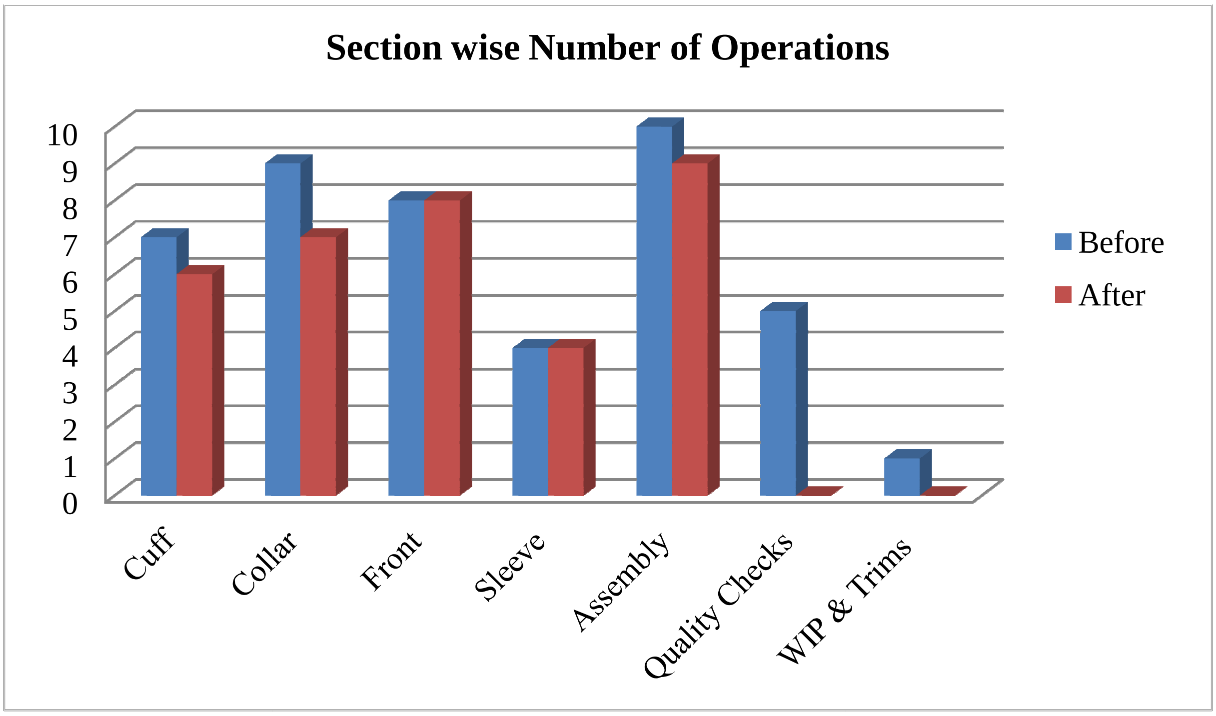

FIGURE 11: Comparison of number of operation indifferent sections

5.4 Comparing Number of Operator Required

In case of batch production, there used to be one operator in each machine and one additional person who can work at least in two to three operations for balancing the flow. The job of this extra operator is to support in critical operations and minimize operational bottlenecks. Whereas in case of single piece flow the operators are allocated as per standard allowed minutes in each cell and they will balance the work according to their need. In single piece flow, the rotation of operators is defined by the SAM and situation of WIP. The number of operators used in different sections is shown in Figure 12.

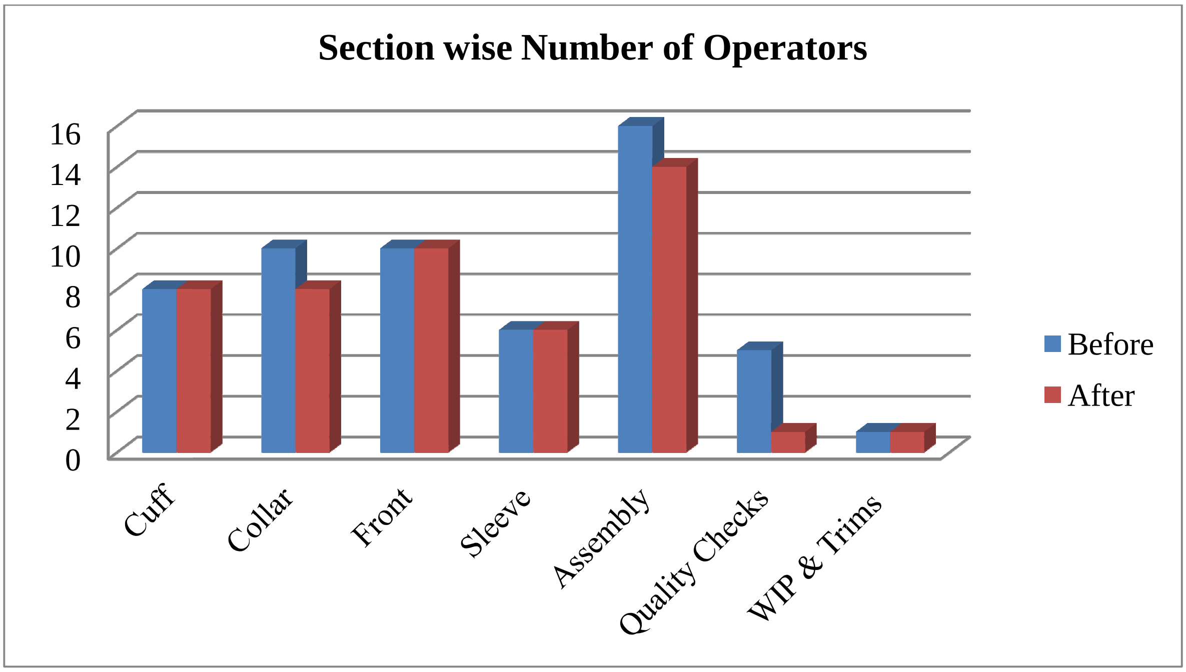

FIGURE 12: Comparison of number of operator required in different sections

Nearly 14% (14.28%) of operators were reduced from batch processing, out of which 8% were from stitching section and 6% from quality checking. The number of operators needed to complete a job is reduced by eliminating some non value added operations from the process. Similarly there is no need of quality checkers after each section, because quality checkers cannot control the quality of work performed before checking. In the earlier system quality checkers were working as the postman, they can give feedback about the produced parts but cannot add any value to the product. So emphasis has been given to the quality of produced parts. For this, the operators were communicated about the required quality standards and specification. In this way if the operator has any confusion or problem during production, he (she) should clear it before working on it. This helps to minimize the rework level, which ultimately increases productivity.

5.5 Comparison of Information Flow

In existing layout the production line is very long, starting from preparatory to the end of assembly. Because of this, communication and information flow is difficult and for each and every thing supervisor has to walk around the line frequently. In case of new layout (cellular layout) the information flow is effective and quick. Because, the group of people who are in the same cell, works in compact area where each operator is in direct contact with other operator of the cell and they know each other's job inside the cell. This makes information flow fast and accurate. Whereas this cannot be achieved in long assembly line; where one operator is in contact with only two operators (one operator before and one operator after his operation) so neither he can give any suggestion nor he knows the issues of other operation i.e. workers are not participating in each other's work, rather working independently.

5.6 Comparison of Rework Level

The rework level has been decreased by 80% over existing trends. In existing production, the rework level is approximately 5% but after implementation of recommended layout the rework level falls to 1%. The main reason for rework reduction is due to reduction in WIP and balanced work cells. Due to low inventory, mistakes are clearly visible and if any defect is found in the garment, it will be cleared inline, and the piece comes out as a final product. In case of batch processing, until the defect is noticed operators may have piled up bunch of WIP and it is very difficult to clear defective parts. In some cases, there may be new style running in the next section before finding defects. This is the most difficult work for clearing defective parts. The older the WIP becomes, the more difficult to clear because there is high possibility of mixing trims (threads, buttons, labels etc.) and confusion regarding style related specifications.

5.7 Operator Skill Improvement

In case of batch processing, due to sitting operation one operator works in one operation only for long time. There is rare chance for operators to do multiple jobs; they do multiple jobs only in critical situations so they don't have much knowledge of another job. They may work more efficiently on the job they were trained but have lack of knowledge for other jobs in the same production line. Whereas in case of cellular manufacturing all operators should have to learn at least three to four operations to balance the cell. This is achieved by rotating operators in between machines for the smooth flow of pieces. In previous batch production, there were only a few operators who know multiple operations, so when the critical operators were absent total output was affected drastically, whereas in case of cellular layout the output will remain consistent irrespective of these factors.

5.8 Operator Motivation

In new layout, operators are motivated because all operators are working in multiple operations in rotation. So there is no arguing that someone is doing a difficult operation and others are working in easier operations. On the other hand, this is not possible in batch production because of specific allocated work for the whole day. Similarly, in case of new layout, operators are treated as a group inside the cell so their combined effort is to do better and produce more. Likewise, operators cannot work carelessly because they will be immediately caught by the next operator inside the cell, so the combined result of all these factors motivates them to do better in each step.

6 RESEARCH SUMMARY

6.1 Conclusion

In this study the lean manufacturing tools and techniques were studied and used in case company (garment manufacturing industry). The problem of batch processing of existing company is addressed by using single piece movement of WIP. This is achieved by converting sitting operation to standing operation and by converting long assembly line into small work cells. Thus by converting long assembly line into work cells, the assumed worker multi-skilling seems effective as well as communication between operators is fast and accurate. The other benefits observed are the flexibility of style changeover and rework reduction. Thus the initial assumptions were solved by this study in the case company.

Firstly, the problem of low flexibility is eliminated by cellular manufacturing, because there is very low WIP inside the process, so the line can be changed immediately if needed. This helps to make different kinds of products in the same production line depending upon requirements, whereas in case of old production layout this cannot be implemented. Because when there is a need to change the style, the pile up of existing WIP takes time to finish before loading new style. In some cases it may take a few days also to clear it whereas the delivery time may pass out by that time. Although, in some exceptional cases, if the management tries to produce urgent orders in the existing line it is very difficult because the running WIP should be packed for future and new style will run in the line. This increases the chances of mixing trims (threads, labels, buttons etc.) of two different styles; which increases rework percentages.

Secondly, by following JIT for production and purchase of items reduces in house WIP which serves two things. First, the unnecessary handling of large amount of raw materials and finished goods is reduced which saves store people’s time as well as warehouse space. Secondly, the working capital requirement is also low because of small order size and fast rotation of fund due to short production lead time. In this way, small amount of money can generate significant profit.

Thirdly, all stitching operations were standardized by means of time and working procedures, this will help management to know the production target per line and can make the production plan before loading actual products in the shop floor. This advance knowledge of the production target helps to allocate production operators on different styles according to the delivery schedule.

Similarly, allocation of workers in different work cells is as per the standard operation time. This motivates operators towards their work, because everybody is given equal work load by this system. At the same time each operator inside the cell should have to work on multiple operations. This eliminates accusing to supervisors for inappropriate allocations of operators in difficult operations.

The other benefit of using cellular manufacturing is consistent output. In existing batch processing, if the critical operators were absent or there is any problem in machines of critical operations, the final output may drop drastically because there are few operators who can work on multiple jobs. Whereas there is no such problem in case of cellular layout, because there are lots of operators who can do multiple operations. This eliminates the problem of production hikes and lows. In this way, consistent output can be achieved in cellular manufacturing.

6.2 Limitations of the Study

This research is limited to the sewing section only, but the lean principles can be implemented in other areas of the shop floor also like cutting and finishing. The lean can bring lots of improvements in cutting area also. For example, even if the small amount of fabric can be saved by the implementation of lean it will save significant amount of money because fabric is the most expensive part of any garment. So the research can be extended to the other areas of the industries also.

The line balancing is made as per manual calculation and assuming every operator knows at least three to four operations of respective cells, but operators may not necessarily know this much operation fluently. Thus while selecting operators for the particular cell it is necessary to check whether the operator is suitable for that work or not because the cell will perform best if all the group members have the same skill level. Thus, if there is a high skill gap, between operators of the same cell it is difficult to balance and will give reduced efficiency.

Normally, the stitching operations are given personal fatigue and delay allowances of 9% to 11%, but due to standing operation and frequent movement from machine to machine this is taken as 15% without any scientific calculation. This needs to be checked with a proper study of ergonomics to get better results.

The study compares different parameters of the existing production system and the recommended system for example production time, rework percentages, operator multi-skilling, operation flexibility etc. but this study cannot correlate all these data to their equivalent financial values. It would be important to do this to attract top management's attention, because the top management can decide whether to continue the lean or stop it by evaluating financial figures.

6.3 Recommendation for Future Research

In this research, only the stitching operations of a formal shirt are standardized due to time limitation and availability of running style during the time of research. But this work can be extended for any new style and data bank should be prepared for other styles also. This will minimize the duplication of work and it is easier to calculate standard time of new style by reallocation of some operations over existing.

In the research the idea of cellular manufacturing has been implemented to increase the productivity. This can be further improved by using the system of group incentive and reward systems. Similarly, the sitting operations have been converted into standing operations for the better movement of operators in between the machines, from the perspective of work balancing and uniform work load distribution. But it is necessary to understand whether this standing operation is appropriate from the ergonomic point of view or not. Similarly if there is any short (long) term health problem of standing operation or not. Because most of the workers were ladies and this mass consists of some pregnant women also. So this issue needs to be reviewed some other way also, rather than productivity point of view only.

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8 LISTS OF APPENDICES

APPENDIX- I

Time Study Data Collection Sheet

Time Study Data Collection Sheet

Date:
Shift:
Name of Operator: Name of Operation:
Machine RPM: Machine Type:
Stitches Per Inch:

Name of Operation	Observed Time					No of Cycles	Total Observed Time	Average Observed Time	Performance Rating	PFD Allowance %	Calculated Time
	1	2	...	..	10						

Note:
PFD: Personal Fatigue and Delay Study Conducted By:

APPENDIX- II

Cuff Section Operation SAM

Stitching Section	Stitching Operations	Observed Time (Sec)	PFD Allowance	Performance Rating	Calculated Time (Sec)
Cuff Section	Cuff Hem	24	15%	100%	27.6
	Cuff Run Stitch	35	15%	100%	40.3
	Cuff Trimming	23	15%	100%	26.5
	Cuff Blocking	20	15%	100%	23.0
	Cuff Top Stitch	33	15%	100%	38.0
	Cuff Button Hole	23	15%	100%	26.5
	Cuff Press	18	15%	100%	20.7
Total Cuff Section		**176**			**202.4**

Collar Section Operation SAM

Stitching Section	Stitching Operations	Observed Time (Sec)	PFD Allowance	Performance Rating	Calculated Time (Sec)
Collar Section	Collar Run Stitch	24	0.15	1	27.6
	Collar Trimming	16	0.15	1	18.4
	Collar Turning & Blocking	16	0.15	1	18.4
	Collar Top Stitch	31	0.15	1	35.65
	Collar Band Hem	15	0.15	1	17.25
	Collar Band Attach	34	0.15	1	39.1
	Collar Peak Ironing	15	0.15	1	17.25
	Collar Band Top Stitch	18	0.15	1	20.7
	Collar Notching	12	0.15	1	13.8
Total Collar Section		**181**			**208.2**

APPENDIX- III

Front Section Operation SAM

Stitching Section	Stitching Operations	Observed Time (Sec)	PFD Allowance	Performance Rating	Calculated Time (Sec)
Front Section	Pocket Marking	13	15%	100%	15.0
	Pocket Hem	15	15%	100%	17.3
	Pocket Iron	35	15%	100%	40.3
	Pocket Attach	45	15%	100%	51.8
	Left Front Placket	25	15%	100%	28.8
	Right Front	32	15%	100%	36.8
	Front Button Hole	36	15%	100%	41.4
	Back Yoke Label Attach	33	15%	100%	38.0
Total Front Section		**234**			**269.1**

Sleeve Section Operation SAM

Stitching Section	Stitching Operations	Observed Time (Sec)	PFD Allowance	Performance Rating	Calculated Time (Sec)
Sleeve Section	Sleeve Placket Attach - continuous placket	40	15%	100%	46.0
	Sleeve Diamond	49	15%	100%	56.4
	Sleeve Pleats	11	15%	100%	12.7
	Sleeve Button Hole	15	15%	100%	17.3
Total Sleeve Section		**115**			**132.3**

APPENDIX- IV

Assembly Section Operation SAM

Stitching Section	Stitching Operations	Observed Time (Sec)	PFD Allowance	Performance Rating	Calculated Time (Sec)
Assembly Section	Back Yoke Attach	26	15%	100%	29.9
	Shoulder Attach	33	15%	100%	38.0
	Sleeve tacking	32	15%	100%	36.8
	Sleeve Attach	40	15%	100%	46.0
	Sleeve Top Stitch	35	15%	100%	40.3
	Side Seam	34	15%	100%	39.1
	Collar Attach	36	15%	100%	41.4
	Collar Close	40	15%	100%	46.0
	Cuff Attach	50	15%	100%	57.5
	Bottom Hem	30	15%	100%	34.5
Total Assembly Section		**356**			**409**

APPENDIX- V

LIST OF GLOSSARY

Batch and Queue: The mass production process of making large lots of a part and then sending the batch to wait in the queue until the next operation in the production process begins.

Bottleneck: Any part of a production line that adversely affects throughput.

Cell: An arrangement of machinery, tools, and personnel designed for most logically and efficiently to complete a production sequence.

Cellular Manufacturing: An approach where manufacturing work centers (cells) have the total capabilities needed to produce an item or group of similar items.

Changeover Time: The time that elapses between the completion of one production run and the beginning of another production run.

Just-in-Time: A production scheduling concept that calls for any item needed at a production operation –whether raw material, finished item, or anything in between, to be produced and available precisely when needed.

Kanban: A Japanese term meaning “visual record” or “card.” In Lean Manufacturing Kanban has come to means “Signal.”

Kanban System: A system that controls production inventory and movement through the visual control of operations.

Mistake Proofing (Poka - Yoke): Technology and procedures designed to prevent defects and equipment malfunction during manufacturing processes.

Visual Controls: Displaying the status of an activity so every employee can see it and take appropriate action.

Non-Value-Added: Activities or actions taken that add no real value to the product or service; these activities are termed as waste.

One-Piece Flow: A situation in which products proceed, one complete product at a time, through various operations in design, order-taking, and production, without interruptions, backflows, or scrap. This is also known as single-piece flow.

Value Stream: The set of specific actions required to bring a specific product through three critical management tasks of any business: problem solving, information management, and physical transformation.

Value Stream Mapping: A process mapping method used to document the current and future states of the information and material flows in a value stream from customer to supplier.

Work In Progress (WIP): Production material in the process of being converted into a saleable product.

Changeovers: Switching from producing one part (product) to another.

Flow Chart: A visual representation of the steps in a process or system.

Gemba: A Japanese term that means "Real Place" or "Where the action takes place."

Inventory: The money and materials invested in by a company in order to create products for sale.

Lead Time: The time required from receipt of order until products are shipped to a customer.

Jidoka: Japanese term meaning automation. In which machinery automatically inspects each item after producing it, ceasing production and notifying humans if a defect is detected.

Standard Allowed Minutes (SAM): This is the amount of time allowed to perform a given task (e.g., a sewing operation) as determined by engineering. Standard Allowed Hours SAH is the time expressed in hours and Standard Allowed Minutes SAM is the time expressed in minutes.

Personal Fatigue and Delay (PFD): PFD allowance is the adjustment done to the normal time to obtain the standard time for the purpose to recover the lost time due to personal needs, fatigue, and unavoidable delays. By providing a small increase to the normal time in each cycle, the worker can still be able to cover lost time and complete the work assigned to him.

Throughput Time: The time period required for a material, part, or subassembly to pass through the manufacturing process.